Billing Code

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

14 CFR Part 25

[Docket No.: FAA-2018-0653; Amdt. No. 25-147]

RIN 2120–AK89

Yaw Maneuver Conditions—Rudder Reversals

AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Final rule.

SUMMARY: The FAA is adding a new load condition to the design standards for transport category airplanes. The new load condition requires such airplanes to be designed to withstand the loads caused by rapid reversals of the rudder pedals, and applies to transport category airplanes that have a powered rudder control surface or surfaces. This rule is necessary because accident and incident data show that pilots sometimes make rudder reversals during flight, even though such reversals are unnecessary and discouraged by flightcrew training programs. The current design standards do not require the airplane structure to withstand the loads that may result from such reversals. If the loads on the airplane exceed those for which it is designed, the airplane structure may fail, resulting in catastrophic loss of control of the airplane. This final rule aims to prevent structural failure of the rudder and vertical stabilizer that may result from these rudder reversals.

DATES: Effective [INSERT DATE 60 DAYS AFTER DATE OF PUBLICATION IN THE FEDERAL REGISTER].

ADDRESSES: For information on where to obtain copies of rulemaking documents and other information related to this final rule, see “How To Obtain Additional Information” in the SUPPLEMENTARY INFORMATION section of this document.

FOR FURTHER INFORMATION CONTACT: For technical questions concerning this action, contact Todd Martin, Materials and Structural Properties Section, AIR-621, Policy and

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SUPPLEMENTARY INFORMATION:

Authority for this Rulemaking

The FAA's authority to issue rules on aviation safety is found in Title 49 of the United States Code. Subtitle I, Section 106 describes the authority of the FAA Administrator. Subtitle VII, Aviation Programs, describes in more detail the scope of the agency's authority.

This rulemaking is promulgated under the authority described in Subtitle VII, Part A, Subpart III, Section 44701, "General Requirements." Under that section, the FAA is charged with promoting safe flight of civil aircraft in air commerce by prescribing regulations and minimum standards for the design and performance of aircraft that the Administrator finds necessary for safety in air commerce. This regulation is within the scope of that authority. It prescribes new safety standards for the design of transport-category airplanes.

I. Overview of Final Rule

This rule adds a new load condition to the design standards in title 14, Code of Federal Regulations (14 CFR) part 25, to require transport category airplanes that have a powered rudder control surface or surfaces to be designed to withstand the loads caused by rapid reversals of the rudder pedals. Specifically, applicants for design approval must show that their proposed airplane design can withstand an initial full rudder pedal input, followed by three full-pedal reversals at the maximum sideslip angle, followed by return of the rudder to neutral. Due to the rarity of such multiple reversals, the rule specifies the new load condition is an ultimate load condition rather than a limit load condition. Consequently, the applicant does not have to apply an additional factor of safety to the calculated load levels.[1]

[1] The terms "limit," "ultimate," and "factor of safety" are addressed in §§ 25.301, 25.303, and 25.305. To summarize, design loads are typically expressed in terms of limit loads, which are then multiplied by a factor of safety, usually 1.5, to determine ultimate loads. In this final rule, the design loads are expressed as ultimate loads and no additional safety factor is applied.

This final rule affects manufacturers of transport category airplanes applying for a new type certificate after the effective date of the final rule. The rule may also affect applicants applying for an amended or supplemental type certificate as determined under 14 CFR § 21.101, "Designation of applicable regulations," after the effective date of the final rule.

The final rule will entail minimal cost, with expected net safety benefits from the reduced risk of rudder reversal accidents.

II. Background

A. Statement of the Problem

The rudder is a vertical control surface on the tail of most airplanes that helps the airplane to turn. Rudder control systems are either powered or unpowered.[2] Accident and incident data show pilots sometimes make multiple and unnecessary rudder reversals during flight. In addition, FAA-sponsored research[3] indicates that pilots use the rudder more often than previously expected and often in ways not recommended by manufacturers. Section 25.1583(a)(3)(ii) requires manufacturers to provide documentation that warns pilots against making large and rapid control reversals, as they may result in structural failures at any speed, including airspeeds below the design maneuvering speed (V_A). Despite the § 25.1583(a)(3)(ii) requirement, and that such rudder reversals are unnecessary and discouraged by flightcrew training programs, these events continue to occur.

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[2] A powered rudder control surface is one in which the force required to deflect the surface against the airstream is generated or augmented by non-mechanical means, such as hydraulic or electric systems. Powered rudder control systems include fly-by-wire and hydro-mechanical systems. An unpowered rudder control surface is one for which the force required to deflect the rudder control surface is transmitted from the pilot's rudder pedal directly to the rudder control surface through mechanical means. Unpowered rudder control systems are also known as mechanical systems. Incorporation of a powered yaw damper into an otherwise unpowered rudder control system does not constitute a powered rudder control system. Other powered systems, such as electrical, hydraulic, or pneumatic systems, may aid in the reduction of pedal forces required for single engine-out operations or to trim out pedal force to maintain a steady heading. However, if such a powered systems does not contribute to hinge moment generation (the twisting force on the rudder surface) during maneuvering of a fully operational airplane, it is not a powered rudder control system.

[3] Report No. DOT/FAA/AM-10/14, "An International Survey of Transport Airplane Pilots' Experiences and Perspectives of Lateral/Directional Control Events and Rudder Issues in Transport Airplanes (Rudder Survey)," dated October 2010, is available in the Docket and at http://www.faa.gov/data_research/research/med_humanfacs/oamtechreports/2010s/media/201014.pdf.

Section 25.351 (“Yaw maneuver conditions”), which sets forth the standard for protecting the airplane’s vertical stabilizer from pilot-commanded maneuver loads, only addresses a single, full rudder input at airspeeds up to the design diving speed (V_D).[4] This design standard does not protect the airplane from the loads imposed by repeated inputs in opposing directions, or rudder reversals.[5] If the loads on the vertical stabilizer exceed those for which it is designed, the vertical stabilizer may fail, resulting in the catastrophic loss of airplane control.

The primary example of this risk is the crash of American Airlines Flight 587 (AA587), which occurred near Queens, New York, on November 12, 2001, and resulted in the death of all 260 passengers and crew aboard and of five persons on the ground. The National Transportation Safety Board (NTSB) found that the probable cause of the accident was “the in-flight separation of the vertical stabilizer [airplane fin] as a result of loads above ultimate design created by the first officer’s unnecessary and excessive rudder pedal inputs.”[6] The NTSB also noted that contributing to these rudder pedal inputs were characteristics of the Airbus A300-600 rudder system design and elements of the American Airlines Advanced Aircraft Maneuvering Program.

Although the AA587 accident is the only catastrophic accident resulting from rudder reversals, other notable accidents and incidents involving airplanes that have a powered control ruder surface have occurred.[7] Ultimate loads were exceeded in two of the other notable rudder reversal events: an incident involving Interflug (Moscow, February 11, 1991) and an accident involving American Airlines Flight 903 (AA903) (near West Palm Beach, Florida, May 12, 1997).[8] The Interflug incident involved multiple rudder reversals, and loads of 1.55 and 1.35

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[4] V_D is the design diving speed: the maximum speed at which the airplane is certified to fly. See 14 CFR 1.2 and 25.335.

[5] A rudder “reversal” is a continuous, pilot-commanded control movement starting from control displacement in one direction followed by control displacement in the opposite direction.

[6] NTSB Aircraft Accident Report NTSB/AAR-04/04, “In-flight Separation of Vertical Stabilizer, American Airlines Flight 587, Airbus Industrie A300-605R, N14053, Belle Harbor, New York, November 12, 2001,” dated October 26, 2004, https://www.ntsb.gov/investigations/AccidentReports/Reports/AAR0404.pdf, p. 160.

[7] FAA Aviation Rulemaking Advisory Committee. Flight Controls Harmonization Working Group. “Rudder Pedal Sensitivity/Rudder Reversal Recommendation Report,” November 7, 2013. (ARAC Rudder Reversal Report). This Report identifies four notable rudder events to which the FAA adds the Interflug incident discussed in the NTSB AA587 Report.

[8] NTSB Aircraft Accident Report NTSB/AAR-04/04, pp. 106-109.

times the limit load were recorded. For the AA903 incident, eight rudder reversals occurred, and a load of 1.53 times the limit load was recorded.[9] A catastrophe similar to AA587 was averted in these two events only because the vertical stabilizers were stronger than required by design standards.[10] In another event, an incident involving Air Canada Flight 190 (AC190) (over the state of Washington, January 10, 2008), four rudder reversals occurred, and the limit load was exceeded by 29 percent.[11] Finally, in an incident involving Provincial Airlines Limited (St. John's, Newfoundland and Labrador, May 27, 2005), the pilot commanded a pedal reversal during climb-out, when the airplane entered an aerodynamic stall.[12] The loads occurring during this event were less than limit loads, but this incident is additional evidence that pedal reversals occur in service.

In 2006, the FAA sponsored a survey[13] to better comprehend transport category pilots' understanding and use of the rudder. This survey inquired of transport pilots from all over the world. The FAA's analysis of the survey data found that—

- Pilots use the rudder more than FAA experts previously thought and often in ways not recommended by manufacturers.
- Pilots make erroneous rudder pedal inputs, some of which include rudder reversals.
- Even after specific training, many pilots are not aware that they should not make rudder reversals, even below V_A. Over the last several years, training and changes to airplane flight manuals directed the pilot to avoid making cyclic control inputs. The rudder reversals that caused the AC190 incident in 2008 and the Provincial Airlines Limited incident in 2005 occurred despite these efforts.

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[9] NTSB Aircraft Accident Report NTSB/AAR-04/04, pp. 104.
[10] NTSB Aircraft Accident Report NTSB/AAR-04/04, pp. 38-39.
[11] Transportation Safety Board of Canada (TSB) Aviation Investigation Report A08W0007, "Encounter with Wake Turbulence," https://www.bst-tsb.gc.ca/eng/rapports-reports/aviation/2008/A08W0007/A08W0007.html.
[12] TSB Aviation Investigation Report A05A0059, "Stall and Loss of Control During Climb," https://www.bst-tsb.gc.ca/eng/rapports-reports/aviation/2005/a05a0059/a05a0059.html.
[13] Report No. DOT/FAA/AM-10/14 (see footnote 3), OMB Control No. 2120-0712.

Pilots in airplane upset situations (e.g., wake vortex encounters) may revert to prior training and make sequential rudder reversals. Based on information from the survey, the FAA expects that repeated rudder reversals will continue to occur despite flightcrew training, because training alone cannot address all potential flightcrew behaviors that can lead to such inputs. For example, the relationship between rudder inputs and the roll and yaw responses of the airplane can become confusing to pilots. This is particularly true with the large yaw and roll rates that result from large rudder inputs, combined with naturally-occurring delays between pedal input and airplane response that result from transport airplane flight dynamics. Such confusion might lead pilots to command repeated rudder reversals.

B. National Transportation Safety Board (NTSB) Recommendation

Following the AA587 accident, the NTSB submitted safety recommendations to the FAA. The NTSB stated, "[f]or airplanes with variable stop rudder travel limiter systems, protection from dangerous structural loads resulting from sustained alternating large rudder pedal inputs can be achieved by reducing the sensitivity of the rudder control system (for example, by increasing the pedal forces), which would make it harder for pilots to quickly perform alternating full rudder inputs."[14] In Safety Recommendation A-04-056,[15] the NTSB recommended the FAA modify part 25 to "include a certification standard that will ensure safe handling qualities in the yaw axis throughout the flight envelope, including limits for rudder pedal sensitivity." This final rule addresses this recommendation and will reduce the likelihood of an event that would be similar to the AA587 accident.

C. Aviation Rulemaking Advisory Committee (ARAC) Activity

In 2011, the FAA tasked the ARAC to consider the need to add a new flight maneuver load condition to part 25, subpart C, that would "ensure airplane structural capability in the presence of rudder reversals" and increasing sideslip angles (yaw angles) at airspeeds up to V_D.

[14] NTSB Safety Recommendation, November 10, 2004, at p. 2. This document is available in the docket and at http://www.ntsb.gov/safety/safety-recs/RecLetters/A04_56_62.pdf.
[15] NTSB Safety Recommendation A-04-056, dated November 10, 2004, is available in the docket and at http://www.ntsb.gov/safety/safety-recs/RecLetters/A04_56_62.pdf.

The FAA also tasked the ARAC to consider whether other airworthiness standards would address this concern, such as pedal characteristics that would discourage pilots from making rudder reversals.[16] The ARAC delegated this task to the Transport Airplane and Engine subcommittee, which assigned it to the Flight Controls Harmonization Working Group (FCHWG) of the subcommittee.

The ARAC FCHWG completed its report in November 2013.[17] ARAC approved the report and submitted it to the FAA on December 30, 2013. One of the recommendations of the ARAC FCHWG Rudder Reversal Report was to require transport category airplanes to be able to withstand safely the loads imposed by three rudder reversals.[18] This final rule adopts that recommendation. The ARAC report indicates that requiring transport category airplanes to operate safely with the vertical stabilizer loads imposed by three full-pedal reversals accounts for most of the attainable safety benefits. With more than three rudder reversals, the ARAC FCHWG found little increase in vertical stabilizer loads.

The report's findings and recommendations guided the formation of the FAA's Yaw Maneuver Conditions—Rudder Reversals notice of proposed rulemaking (NPRM) (83 FR 32087, July 16, 2018) and this final rule.

D. Summary of the NPRM

On July 16, 2018, the FAA published an NPRM that proposed to add a new regulation to address rudder reversal conditions on transport category airplanes (83 FR 32087). The FAA intended that this new requirement would prevent structural failure of the rudder and vertical stabilizer caused by reversals of the rudder pedals. Thus, the FAA proposed to require that

[16] The FAA published this notice of ARAC tasking in the *Federal Register* on March 28, 2011. Aviation Rulemaking Advisory Committee; Transport Airplane and Engine Issues—New Task, 76 F.R. 17183.
[17] ARAC FCHWG Recommendation Report, "Rudder Pedal Sensitivity/Rudder Reversal," dated November 7, 2013, is available in the Docket and at https://www.faa.gov/regulations_policies/rulemaking/committees/documents/media/TAEfch-rpsrr-3282011.pdf.
[18] One member of the ARAC FCHWG did not support any rulemaking. The remaining members of the ARAC FCHWG found that a yaw maneuver load condition would be the optimal way to protect the airplane from the excessive loads that can result from multiple rudder reversals because they found systems solutions, such as fly-by-wire systems and manual systems with appropriate yaw dampers, to be too design-prescriptive. The members of the ARAC FCHWG held divided opinions, however, on what the load condition should be.

airplanes be able to withstand the structural loads caused by three full reversals (doublets) of the rudder pedals. The FAA proposed to apply the requirement only to airplanes with powered rudder control surfaces.

E. Rulemaking by the European Union Aviation Safety Agency (EASA)

On November 5, 2018, EASA published amendment 22 to Certification Specifications 25 (CS-25). This amendment included a new regulation, CS 25.353, "Rudder control reversal conditions," as well as Acceptable Means of Compliance 25.353. EASA's new regulation is similar to this final rule except that the final rule adopted by the FAA applies only to airplanes that have a powered rudder control surface or surfaces.

F. Advisory Material

FAA Advisory Circular (AC) 25.353-1, "Rudder Control Reversal Conditions," which accompanies this rule, provides guidance on acceptable means, but not the only means, of showing compliance with § 25.353. AC 25.353-1 is available in the public docket for this rulemaking.

III. Discussion of Public Comments and Final Rule

The FAA received comments from the NTSB, Airline Pilots Association, International (ALPA), ATR, Crew Systems, Textron Aviation, Airbus, The Boeing Company, and Bombardier Aerospace. The NTSB, ALPA, ATR, and Crew Systems supported the proposal and did not suggest changes to it. Textron Aviation and Airbus requested that the rule specify a single, full-pedal command followed by one rudder reversal and return to neutral, rather than three rudder reversals as proposed in the NPRM. Those two companies, along with Boeing, also requested other changes, as described in this section of the preamble. Bombardier Aerospace commented on the rule's cost, suggesting that the FAA issue guidance to limit the rule's applicability.

A. Necessity of Three Reversals

In the NPRM, the FAA proposed a design load condition that consists of a single, full-pedal command followed by three full-pedal reversals and return to neutral. Two airplane manufacturers, Textron Aviation and Airbus, requested that the rule instead specify a single, full-pedal command followed by one rudder reversal and return to neutral. These companies believed this condition was more appropriate given the rarity of rudder reversals and the uniqueness of the AA587 accident airplane. They advocated that a single, full-pedal command followed by one rudder reversal and return to neutral would cover all other known incidents, stated their concern that the proposed criteria could result in weight penalties or detrimental system changes, and proposed that enhanced flightcrew training would be more effective than designing for multiple rudder reversals.

The FAA emphasizes that while rudder reversals are rare, they can lead to serious consequences. The AA587 accident and four other accidents and incidents involved multiple rudder reversals, some of which were full-pedal reversals. Since these accidents occurred, modern airplane design requirements have not changed in a manner that would deter pilots from making such multiple reversals. Additionally, based on information received in response to the 2006 pilot survey, the FAA found that some respondents reported making rudder pedal reversals (cyclic rudder-pedal commands).[19] Moreover, an analysis in the ARAC report shows that loads would continue to increase upon subsequent pedal reversals. Therefore, a single, full-pedal command followed by one full-pedal reversal and return to neutral would not represent the conditions resulting from multiple full-pedal reversals that may result in injuries to occupants or a structural failure that jeopardizes continued safe flight and landing of the airplane. Data from all manufacturers on the ARAC FCHWG showed that after three full-pedal reversals, the maximum sideslip angle does not increase significantly. Maximum sideslip angle causes the

[19] Report No. DOT/FAA/AM-10/14 at p. 14 (see footnote 3).

maximum loads on the vertical stabilizer; therefore, three full-pedal reversals result in a load condition that accounts for most of the attainable safety benefits.

Regarding the concern that the proposed multiple reversal condition could result in potential weight penalties or detrimental system changes in future designs, as discussed in the NPRM preamble, the FAA expects that most applicants will use control laws to comply with this rule. Because manufacturers typically implement control laws through systems and software, use of this solution to comply would result in little to no incremental cost in the form of weight, equipment, maintenance, or training for those airplanes with powered rudder control surfaces.

Based on information from the 2006 survey, the FAA does not agree with Textron and Airbus that enhanced flight crew training would be more effective than designing for multiple full-pedal reversals. As described earlier in the preamble, the FAA's analysis of the survey found that even after specific training, many pilots are not aware that they should not make full-pedal reversals, even below V_A. While training and changes to airplane flight manuals directed the pilot to avoid making cyclic control inputs, the pedal reversals that caused the AC190 incident in 2008 and the Provincial Airlines Limited incident in 2005 occurred despite these efforts.

Moreover, in transport category airplanes, rudder inputs are generally limited to aligning the airplane with the runway during crosswind landings and controlling engine-out situations, which occur predominately at low speeds. At high speeds, the pilot normally directly rolls the airplane using the ailerons.[20] If the pilot does use the rudder to control the airplane at high speeds, there will be a significant phase lag between the rudder input and the roll response because the roll response is a secondary effect of the yawing moment generated by the rudder.[21] The roll does not result from the rudder input directly. Even if the rudder is subsequently deflected in the opposite direction (rudder reversal), the airplane can continue to roll and yaw in

[20] An aileron is a hinged control service on the trailing edge of the wing of a fixed-wing aircraft, one aileron per wing.

[21] The yaw axis is defined to be perpendicular to the wings and to the normal line of flight. A yaw movement is a change in the direction of the aircraft to the left or right around the yaw axis.

one direction before reversing because of the phase lag. The relationship between rudder inputs and the roll and yaw response of the airplane can become confusing to pilots, particularly with the large yaw and roll rates that would result from large rudder inputs, causing the pilots to input multiple rudder reversals.

For the foregoing reasons, the FAA has determined that a three full-pedal reversal condition is necessary to account for the effects of multiple rudder reversals that the FAA expects to occur in service. The FAA adopts this aspect of the proposal without change.

B. Applicability

Airbus requested that the rule apply only to new aircraft designs; Bombardier requested that the rule apply only to new airplanes or to airplanes where the rudder system has been significantly modified. The FAA agrees in part with the comments regarding applicability. This final rule requires that new airplane designs meet the new standards. Where an applicant proposes a change to a previously approved type design, § 21.101, "Designation of applicable regulations," requires an assessment to determine the amendment level (version) of each regulation to be applied to that type design change. The FAA would determine under the provisions of § 21.101 whether this final rule would be applied to a changed airplane design.

Additionally, Airbus requested that the rule apply to all transport category airplanes, including those with unpowered control surfaces. Similarly, the corresponding and recently adopted European Union Aviation Safety Agency (EASA) rule, CS 25.353, applies to all airplanes, including those with unpowered control surfaces. However, in the NPRM, the FAA proposed to apply this rule only to airplanes with a powered control surface or surfaces.

A powered rudder control surface is one in which the force required to deflect the surface against the airstream is generated or augmented by hydraulic or electric systems. In contrast, an unpowered rudder control surface is one for which the force required to deflect the surface against the airstream is transmitted from the pilot's rudder pedal directly through mechanical means, without any augmentation from hydraulic or electrical systems. Powered rudder control systems include fly-by-wire (FBW) and hydro-mechanical systems, while unpowered rudder control systems are also known as mechanical systems. Incorporation of a powered yaw damper into an otherwise unpowered rudder control system does not constitute a powered rudder control surface, for the purpose of this rule.

Small business jets that typically have unpowered rudder control surfaces provide immediate feedback to their flightcrews in response to yaw inputs. Those flightcrews are, therefore, less likely to execute inappropriate rudder pedal reversals. The FAA reviewed accident and incident records and found no events in which pilots commanded inappropriate full-pedal reversals on airplanes with unpowered rudder control surfaces. Also, the use of airplanes with unpowered rudder control surfaces is diminishing in the transport category fleet. The only transport category airplane model in U.S. production with an unpowered rudder control surface also has a yaw damper. The normal operation of the yaw damper would be adequate to reduce yaw overshoot loads from full-pedal reversals.

As explained in the NPRM and this final rule, the safety benefit of expanding this rule to airplanes with unpowered control surfaces does not outweigh the potentially higher costs of implementation. The FAA may consider the requested change later if data or information become available to indicate that either the safety case has changed or implementation costs have decreased.

C. Load Condition Requirements

Airbus and Boeing requested the FAA include in the rule the following text: "Flaps (or flaperons or any other aerodynamic devices when used as flaps) and slats extended configurations are also to be considered if they are used in en route conditions." Including this provision would require applicants to evaluate the rudder reversal conditions with flaps and other devices extended, if the airplane uses those devices in en route conditions.[22] Airbus also

[22] En route conditions means the conditions occurring during any phase of flight after initial climb and before the final descent and landing phase.

requested that the rule include the following text: "Unbalanced aerodynamic moments about the center of gravity must be reacted in a rational or conservative manner considering the airplane inertia forces." This language specifies how the applicant sums the various forces when analyzing the rudder reversal conditions. Both commenters requested the FAA include these requirements in the final rule to be consistent with the ARAC FCHWG report and to harmonize with the EASA regulation.

The FAA agrees that the additions identified by commenters should be included in the final rule because both requirements harmonize with the EASA rule (CS 25.353) and clarify how to analyze the load conditions. The two requirements are also found in other part 25 regulations, including §§ 25.345 and 25.351. The FAA notes that the requirement to consider the effect of flaps and slats in en route conditions has slightly different wording than the EASA rule, but has the same meaning. As these changes simply clarify how to analyze the load conditions, they will not add additional burdens.

Airbus also requested that the airplane be able to withstand the prescribed conditions at an uppermost speed of V_C, rather than V_C/M_C, as proposed in the NPRM. The FAA disagrees with the commenter. The proposed rule included V_C/M_C because airplanes have defined limitations for both V_C and M_C. However, no substantive difference between the two exists because each value of V_C has a corresponding value of M_C. As a result, using V_C/M_C is appropriate in this rule.

<u>D. Warning Monitors</u>

Airbus requested that the rule allow an applicant to show compliance via implementing monitors that would warn the pilot of inappropriate rudder use. The FAA does not agree with this comment. Pilot-commanded rudder reversals have occurred during high workload and conditions that are often startling. Thus, depending on the pilot to react appropriately to a warning under such conditions would not provide the equivalent safety benefit as the load conditions in this final rule and would be inconsistent with the EASA regulation.

E. Miscellaneous Modifications

As previously noted, EASA published its regulation, CS 25.353, on November 5, 2018, a few months after the FAA issued the NPRM upon which this final rule is based. This final rule contains minor modifications to harmonize with the EASA standard. These modifications are in addition to those described earlier in the final rule (C. Load Condition Requirements). These modifications include:

(1) The proposed rule specified that the applicant evaluate the rudder reversal conditions "from V_{MC} or the highest airspeed for which it is possible to achieve maximum rudder deflection at zero sideslip, whichever is greater, up to V_C/M_C." This final rule establishes the speed range as "V_{MC} to V_C/M_C." This is simpler to apply because it does not require an additional calculation of "the highest speed for which it is possible …" and it is consistent with the current rudder maneuver condition required by § 25.351. (Section 25.351 prescribes the speed range as V_{MC} to V_D.)

(2) This final rule provides that any permanent deformation resulting from the specified ultimate load conditions must not prevent continued safe flight and landing. This requirement is necessary because this final rule, unlike most design load conditions codified in part 25, contains only an "ultimate" load requirement, and does not contain a "limit" load requirement. Design loads are typically expressed in terms of limit loads, which are then multiplied by a factor of safety, usually 1.5, to determine ultimate loads. The airplane structure must be able to withstand limit loads without detrimental permanent deformation and ultimate loads without failure in accordance with § 25.305. Because this rule does not include a limit load requirement, it is necessary to require that no detrimental permanent deformation occur at ultimate load (deformation that would prevent continued safe flight and landing). This requirement is also in the corresponding EASA regulation, CS 25.353.

(3) The proposed rule specified that the "rudder control is suddenly displaced" in evaluating the ultimate loads that result from the yaw maneuver conditions identified in the

proposal. This final rule, however, specifies that the "rudder control is suddenly and fully displaced as limited by the control system or control surface stops." The term "fully" makes it clear that full displacement of the rudder pedal is required. The phrase "as limited by the control system or control surface stops" further clarifies the requirement by indicating that the conditions may be conducted using rudder control system limiting hardware to establish the reversal loads. Furthermore, the aforementioned requirements are consistent with § 25.351.

IV. Regulatory Notices and Analyses

Changes to Federal regulations must undergo several economic analyses. First, Executive Orders 12866 and 13563 direct that each Federal agency shall propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs. Second, the Regulatory Flexibility Act of 1980 (Pub. L. 96-354), as codified in 5 U.S.C. 603 et seq., requires agencies to analyze the economic impact of regulatory changes on small entities. Third, the Trade Agreements Act of 1979 (Pub. L. 96–39), 19 U.S.C. Chapter 13, prohibits agencies from setting standards that create unnecessary obstacles to the foreign commerce of the United States. In developing U.S. standards, the Trade Agreements Act requires agencies to consider international standards and, where appropriate, that they be the basis of U.S. standards. Fourth, the Unfunded Mandates Reform Act of 1995 (Pub. L. 104–4), as codified in 2 U.S.C. Chapter 25, requires agencies to prepare a written assessment of the costs, benefits, and other effects of proposed or final rules that include a Federal mandate likely to result in the expenditure by State, local, or tribal governments, in the aggregate, or by the private sector, of $100 million or more annually (adjusted for inflation with base year of 1995). This portion of the preamble summarizes the FAA's analysis of the economic impacts of this final rule.

In conducting these analyses, the FAA has determined that this final rule has benefits that justify its costs and is not a ''significant regulatory action'' as defined in section 3(f) of Executive Order 12866. The final rule is also not ''significant'' as defined in DOT's rulemaking procedures. The final rule will not have a significant economic impact on a substantial number of small entities, will not create unnecessary obstacles to the foreign commerce of the United States, and will not impose an unfunded mandate on State, local, or tribal governments, or on the private sector by exceeding the threshold identified previously.

A. Regulatory Evaluation

1. Background and Statement of Need

The genesis of this final rule is the crash of American Airlines Flight 587 (AA587), near Queens, New York, on November 12, 2001, resulting in the death of all 260 passengers and crew aboard, and the death of five persons on the ground. The airplane was destroyed by impact forces and a post-crash fire.

The NTSB found that the probable cause of the accident was "the in-flight separation of the vertical stabilizer [airplane fin] as a result of loads above ultimate design created by the first officer's unnecessary and excessive rudder pedal inputs."[23] Ultimate loads on the airplane structure are the limit loads (1.0) multiplied by a safety factor, usually 1.5 (as for the vertical stabilizer). An airplane is expected to experience a limit load once in its lifetime and is never expected to experience an ultimate load.[24] For the AA587 accident, loads exceeding ultimate loads ranged from 1.83 to 2.14 times the limit load on the vertical stabilizer,[25] as a result of four, full, alternating rudder inputs known as "rudder reversals."

Significant rudder reversal events are unusual in the history of commercial airplane flight, having occurred during five notable accidents and incidents, with the AA587 accident being the only catastrophic accident resulting from rudder reversals.[26] Ultimate loads were exceeded in two of the other notable rudder reversal events: an incident involving Interflug

[23] NTSB Aircraft Accident Report NTSB/AAR-04/04, "In-flight Separation of Vertical Stabilizer, American Airlines Flight 587, Airbus Industrie A300-605R, N14053, Belle Harbor, New York, November 12, 2001" at 160 (Oct. 26, 2004), *available at* https://www.ntsb.gov/investigations/AccidentReports/Reports/AAR0404.pdf.
[24] NTSB Aircraft Accident Report NTSB/AAR-04/04, p. 31, n. 53.
[25] NTSB Aircraft Accident Report NTSB/AAR-04/04, p. 104.
[26] FAA Aviation Rulemaking Advisory Committee. Flight Controls Harmonization Working Group. "Rudder Pedal Sensitivity/Rudder Reversal Recommendation Report," November 7, 2013. (ARAC Rudder Reversal Report). This Report identifies four notable rudder events to which the FAA adds the Interflug incident discussed in the NTSB AA587 Report.

(Moscow, February 11, 1991) and an accident involving American Airlines Flight 903 (AA903) (near West Palm Beach, Florida, May 12, 1997).[27] The Interflug incident involved multiple rudder reversals, and loads of 1.55 and 1.35 times the limit load were recorded. For the AA903 incident, eight rudder reversals occurred, and a load of 1.53 times the limit load was recorded.[28] A catastrophe similar to AA587 was averted in these two events only because the vertical stabilizers were stronger than required by design standards.[29] In a fourth event—Air Canada Flight 190 (AC190) (over the state of Washington, January 10, 2008)—four rudder reversals occurred, and the limit load was exceeded by 29 percent.[30] The fifth event was a de Havilland DHC-8-100 (Dash 8) (St. John's, Newfoundland and Labrador, May 27, 2005) in which the pilot commanded a pedal reversal during climb-out, when the airplane entered an aerodynamic stall.[31] There were no injuries, and the airplane was not damaged. The ARAC FCHWG determined the loads occurring during this event were less than limit load, but this incident is additional evidence that pedal reversals occur in service.

In transport category airplanes, rudder inputs are generally limited to aligning the airplane with the runway during crosswind landings and controlling engine-out situations, which occur predominately at low speeds. At high speeds, the pilot normally directly rolls the airplane using the ailerons.[32] If the pilot does use the rudder to control the airplane at high speeds, there will be a significant phase lag between the rudder input and the roll response because the roll response is a secondary effect of the yawing moment generated by the rudder.[33] The roll does not

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[27] NTSB Aircraft Accident Report NTSB/AAR-04/04, pp. 106-109; *see also* NTSB Aircraft Accident Report AA903 (NTSB DCA97MA049).
[28] NTSB Aircraft Accident Report NTSB/AAR-04/04, pp. 104; *Report on the Investigation of the Abnormal Behavior of an Airbus A310-304 Aircraft on 11.02.199 at Moscow*, Air Accident Investigation Department of the German Federal Office of Aviation, Reference 6X002-0/91.
[29] NTSB Aircraft Accident Report NTSB/AAR-04/04, pp. 38-39.
[30] Transportation Safety Board of Canada (TSB) Aviation Investigation Report A08W0007, "Encounter with Wake Turbulence," https://www.bst-tsb.gc.ca/eng/rapports-reports/aviation/2008/A08W0007/A08W0007.html.
[31] TSB Aviation Investigation Report A05A0059, "Stall and Loss of Control During Climb," https://www.bst-tsb.gc.ca/eng/rapports-reports/aviation/2005/a05a0059/a05a0059.html.
[32] An aileron is a hinged control service on the trailing edge of the wing of a fixed-wing aircraft, one aileron per wing.
[33] The yaw axis is defined to be perpendicular to the wings and to the normal line of flight. A yaw movement is a change in the direction of the aircraft to the left or right around the yaw axis.

result from the rudder input directly. Even if the rudder is subsequently deflected in the opposite direction (rudder reversal), the airplane can continue to roll and yaw in one direction before reversing because of the phase lag. The relationship between rudder inputs and the roll and yaw response of the airplane can become confusing to pilots, particularly with the large yaw and roll rates that would result from large rudder inputs, causing the pilots to input multiple rudder reversals.

Following the AA587 accident in November 2004, the NTSB issued Safety Recommendation A-04-56, recommending that the FAA modify part 25 "to include a certification standard that will ensure safe handling qualities in the yaw axis throughout the flight envelope…."[34] In 2011, the FAA tasked ARAC to consider the need for rulemaking to address the rudder reversal issue. ARAC delegated this task to the Transport Airplane and Engine subcommittee, which assigned it to the FCHWG. One of the recommendations of the ARAC FCHWG Rudder Reversal Report, issued on November 7, 2013, was to require transport category airplanes to be able to withstand safely the loads imposed by three rudder reversals. This final rule adopts that recommendation. The ARAC report indicates that requiring transport category airplanes to operate safely with the vertical stabilizer loads imposed by three full-pedal reversals accounts for most of the attainable safety benefits. With more than three rudder reversals, the FCHWG found little increase in vertical stabilizer loads.

2. Impacts of this Final Rule

Since the catastrophic AA587 accident, the FAA has requested that applicants for new type certificates show that their designs are capable of continued safe flight and landing after experiencing repeated rudder reversals. For airplanes with fly-by-wire (FBW) systems, manufacturers have been able to show capability by means of control laws, incorporated through software changes, adding no weight and imposing no additional maintenance cost to the

[34] NTSB Safety Recommendation A-04-56 (Nov. 10, 2004), *available at* https://www.ntsb.gov/safety/safety-recs/RecLetters/A04_56_62.pdf.

airplanes. Many, if not all, of these designs have demonstrated tolerance to three or more rudder reversals. Aside from converting to an FBW or hydro-mechanical system, alternatives available to manufacturers specializing in airplane designs with mechanical rudders include increasing the reliability of the yaw damper and strengthening the airplane vertical stabilizer.

To estimate the cost of the final rule, the FAA reviewed unit cost estimates from U.S. airplane manufacturers and incorporated these estimates into an airplane life cycle model. The FAA received one estimate for large part 25 airplanes and two estimates for small part 25 airplanes (i.e., business jets).

A manufacturer specializing in mechanical rather than FBW rudder systems provided a business jet estimate that reflects significantly higher compliance costs. This manufacturer's most cost-efficient approach to addressing the requirement—although high in comparison to manufacturers that use FBW systems exclusively—is to comply with a strengthened vertical stabilizer. The cost of complying with a more reliable yaw damper was higher than strengthening the vertical stabilizer, and higher still if complying by converting to an FBW rudder system for new models.

As a result of these high costs and the reasons set forth in the NPRM and the preceding "Discussion of Comments and Final Rule," this final rule will not apply to airplanes with unpowered (mechanical) rudder control surfaces. An unpowered rudder control surface is one whose movement is affected through mechanical means, without any augmentation (for example, from hydraulic or electrical systems). Accordingly, the final rule does not apply to models with mechanical rudder control systems, but applies only to models with FBW or hydro-mechanical rudder systems.

The FAA estimates the costs of the final rule using unit cost per model estimates from industry for FBW models and the agency's estimates of the number of new large airplane and business jet certifications with FBW rudder systems in the ten years after the effective date of the final rule. These estimates are shown in Table 1.

Table 1. Cost Estimated for Final Rule ($ 2016)

	Cost per Model	No. of New FBW Models (10 yrs)	Costs
Large Airplanes	$300,000	2	$ 600,000
Business Jets	$235,000	2	$ 470,000
Total Costs			$ 1,070,000

With these cost estimates, the FAA concludes the final rule will entail minimal cost, with expected net safety benefits from the reduced risk of rudder reversal accidents.

B. Regulatory Flexibility Determination

The Regulatory Flexibility Act of 1980 (Pub. L. 96-354) (RFA) establishes "as a principle of regulatory issuance that agencies shall endeavor, consistent with the objectives of the rule and of applicable statutes, to fit regulatory and informational requirements to the scale of the businesses, organizations, and governmental jurisdictions subject to regulation. To achieve this principle, agencies are required to solicit and consider flexible regulatory proposals and to explain the rationale for their actions to assure that such proposals are given serious consideration." The RFA covers a wide range of small entities, including small businesses, not-for-profit organizations, and small governmental jurisdictions.

Agencies must perform a review to determine whether a rule will have a significant economic impact on a substantial number of small entities. If the agency determines that it will, the agency must prepare a regulatory flexibility analysis as described in the RFA. However, if an agency determines that a rule is not expected to have a significant economic impact on a substantial number of small entities, section 605(b) of the RFA provides that the head of the agency may so certify and a regulatory flexibility analysis is not required. The certification must include a statement providing the factual basis for this determination, and the reasoning should be clear.

As noted above, because manufacturers with FBW rudder systems have been able to show compliance by means of low-cost changes to control laws incorporated through software changes, the FAA estimates the costs of this final rule to be minimal. Therefore, pursuant to section 605(b), the head of the FAA certifies that this final rule will not have a significant economic impact on a substantial number of small entities.

C. International Trade Impact Assessment

The Trade Agreements Act of 1979 (Pub. L. 96-39) prohibits Federal agencies from establishing standards or engaging in related activities that create unnecessary obstacles to the foreign commerce of the United States. Pursuant to this Act, the establishment of standards is not considered an unnecessary obstacle to the foreign commerce of the United States, so long as the standard has a legitimate domestic objective, such as the protection of safety, and does not operate in a manner that excludes imports that meet this objective. The statute also requires consideration of international standards and, where appropriate, that they be the basis for U.S. standards.

The FAA has assessed the effect of this final rule and determined that its purpose is to protect the safety of U.S. civil aviation. Therefore, the final rule is in compliance with the Trade Agreements Act.

D. Unfunded Mandates Assessment

Title II of the Unfunded Mandates Reform Act of 1995 (Pub. L. 104-4) requires each Federal agency to prepare a written statement assessing the effects of any Federal mandate in a proposed or final agency rule that may result in an expenditure of $100 million or more (in 1995 dollars) in any one year by State, local, and tribal governments, in the aggregate, or by the private sector; such a mandate is deemed to be a “significant regulatory action.” The FAA currently uses an inflation-adjusted value of $155.0 million in lieu of $100 million.

This final rule does not contain such a mandate. Therefore, the requirements of Title II of the Act do not apply.

E. Paperwork Reduction Act

The Paperwork Reduction Act of 1995 (44 U.S.C. 3507(d)) requires that the FAA consider the impact of paperwork and other information collection burdens imposed on the public. The FAA has determined that there is no new requirement for information collection associated with this final rule.

F. International Compatibility

In keeping with U.S. obligations under the Convention on International Civil Aviation, it is FAA policy to conform to International Civil Aviation Organization (ICAO) Standards and Recommended Practices to the maximum extent practicable. The FAA has determined that there are no ICAO Standards and Recommended Practices that correspond to these regulations.

G. Environmental Analysis

FAA Order 1050.1F, Environmental Impacts: Policies and Procedures, identifies FAA actions that are categorically excluded from preparation of an environmental assessment or environmental impact statement under the National Environmental Policy Act in the absence of extraordinary circumstances. The FAA has determined this rulemaking action qualifies for the categorical exclusion identified in paragraph 5-6.6 for regulations and involves no extraordinary circumstances.

V. Executive Order Determinations

A. Executive Order 13132, Federalism

The FAA has analyzed this final rule under the principles and criteria of Executive Order 13132, Federalism. The agency determined that this action will not have a substantial direct effect on the States, or the relationship between the Federal Government and the States, or on the distribution of power and responsibilities among the various levels of government, and, therefore, does not have Federalism implications.

B. Executive Order 13211, Regulations that Significantly Affect Energy Supply, Distribution, or Use

The FAA analyzed this final rule under Executive Order 13211, Actions Concerning Regulations that Significantly Affect Energy Supply, Distribution, or Use (May 18, 2001). The agency has determined that it is not a "significant energy action" under the executive order and it is not likely to have a significant adverse effect on the supply, distribution, or use of energy.

C. Executive Order 13609, International Cooperation

Executive Order 13609, Promoting International Regulatory Cooperation, (77 FR 26413, May 4, 2012) promotes international regulatory cooperation to meet shared challenges involving health, safety, labor, security, environmental, and other issues and reduce, eliminate, or prevent unnecessary differences in regulatory requirements. The FAA has analyzed this action under the policy and agency responsibilities of Executive Order 13609. The agency has determined that this action would eliminate differences between U.S. aviation standards and those of other civil aviation authorities by harmonizing with the corresponding EASA requirement. As noted above, EASA published its corresponding regulation, CS 25.353, on November 5, 2018. This final rule harmonizes with that standard, with the exception that this rule excludes airplanes that have an unpowered rudder control surface(s).

VI. How to Obtain Additional Information

A. Rulemaking Documents

An electronic copy of a rulemaking document may be obtained by using the Internet—

1. Search the Federal eRulemaking Portal (http://www.regulations.gov);
2. Visit the FAA's Regulations and Policies Web page at http://www.faa.gov/regulations_policies/; or
3. Access the Government Printing Office's Web page at http://www.gpo.gov/fdsys/.

Copies may also be obtained by sending a request (identified by notice, amendment, or docket number of this rulemaking) to the Federal Aviation Administration, Office of

Rulemaking, ARM-1, 800 Independence Avenue SW., Washington, DC 20591, or by calling (202) 267-9680.

B. Comments Submitted to the Docket

Comments received may be viewed by going to http://www.regulations.gov and following the online instructions to search the docket number for this action. Anyone is able to search the electronic form of all comments received into any of the FAA's dockets by the name of the individual submitting the comment (or signing the comment, if submitted on behalf of an association, business, labor union, etc.).

C. Small Business Regulatory Enforcement Fairness Act

The Small Business Regulatory Enforcement Fairness Act (SBREFA) of 1996 (Pub. L. 104-121) (set forth as a note to 5 U.S.C. 601) requires the FAA to comply with small entity requests for information or advice about compliance with statutes and regulations within its jurisdiction. A small entity with questions regarding this document may contact its local FAA official or the person listed under the FOR FURTHER INFORMATION CONTACT heading at the beginning of the preamble. To find out more about SBREFA on the Internet, visit http://www.faa.gov/regulations_policies/rulemaking/sbre_act/.

List of Subjects in 14 CFR Part 25

Aircraft, Aviation safety, Reporting and recordkeeping requirements.

The Amendment

In consideration of the foregoing, the Federal Aviation Administration amends chapter I of title 14, Code of Federal Regulations as follows:

PART 25—AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY AIRPLANES

1. The authority citation for part 25 continues to read as follows:

Authority: 49 U.S.C. 106(f), 106(g), 40113, 44701, 44702 and 44704.

2. Add § 25.353 under the undesignated center heading "Flight Maneuver and Gust Conditions" to read as follows:

§ 25.353 Rudder control reversal conditions.

Airplanes with a powered rudder control surface or surfaces must be designed for loads, considered to be ultimate, resulting from the yaw maneuver conditions specified in paragraphs (a) through (e) of this section at speeds from V_{MC} to V_C/M_C. Any permanent deformation resulting from these ultimate load conditions must not prevent continued safe flight and landing. The applicant must evaluate these conditions with the landing gear retracted and speed brakes (and spoilers when used as speed brakes) retracted. The applicant must evaluate the effects of flaps, flaperons, or any other aerodynamic devices when used as flaps, and slats-extended configurations, if they are used in en route conditions. Unbalanced aerodynamic moments about the center of gravity must be reacted in a rational or conservative manner considering the airplane inertia forces. In computing the loads on the airplane, the yawing velocity may be assumed to be zero. The applicant must assume a pilot force of 200 pounds when evaluating each of the following conditions:

(a) With the airplane in unaccelerated flight at zero yaw, the flightdeck rudder control is suddenly and fully displaced to achieve the resulting rudder deflection, as limited by the control system or the control surface stops.

(b) With the airplane yawed to the overswing sideslip angle, the flightdeck rudder control is suddenly and fully displaced in the opposite direction, as limited by the control system or control surface stops.

(c) With the airplane yawed to the opposite overswing sideslip angle, the flightdeck rudder control is suddenly and fully displaced in the opposite direction, as limited by the control system or control surface stops.

(d) With the airplane yawed to the subsequent overswing sideslip angle, the flightdeck rudder control is suddenly and fully displaced in the opposite direction, as limited by the control system or control surface stops.

(e) With the airplane yawed to the opposite overswing sideslip angle, the flightdeck rudder control is suddenly returned to neutral.

Issued under authority provided by 49 U.S.C. 106(f), and 44701(a) in Washington, DC, on or about November 16, 2022.

Billy Nolen
Acting Administrator
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